COMPARING THE FOREST FLOOR AND SURFACE SOIL BENEATH FOUR PINE SPECIES IN THE VIRGINIA PIEDMONT

by

Louis J. Metz, Carol G. Wells, and Paul P. Kormanik

In March of 1945 a species comparison study was established on the Lee Experimental Forest in Buckingham County, Virginia. The purpose of the study was to determine which of four conifers—loblolly pine (*Pinus taeda* L.), shortleaf pine (*P. echinata* Mill.), Virginia pine (*P. virginiana* Mill.), and white pine (*P. strobus* L.)—would be the most desirable species for planting on poorer upland Piedmont sites where hardwood establishment is generally unsuccessful.

The study reported here was undertaken to determine if the four pine species produced different forest floors, and if the trees modified the surface mineral soil to different extents.

The plantings, consisting of 10 randomized blocks, were made on abandoned fields in the same stage of plant succession, i. e., broomsedge (*Andropogon* spp.) with scattered pine reproduction. No maps were prepared and no analyses were made on the soils before the study was begun. Trees were measured periodically; the 1961 measurements are shown in table 1. This table is reproduced from a previous report by Kormanik and Hoekstra,[1] where more detail on the survival and growth of the plantings can be found.

[1]Kormanik, P. P., and Hoekstra, P. E. A comparson of loblolly, white, Virginia, and shortleaf pine in the Virginia Piedmont. Southeast. Forest Exp. Sta., U. S. Forest Serv. Res. Note SE-11, 3 pp. 1963.

Metz and Wells are Principal Soil Scientists at the Forestry Sciences Laboratory, Research Triangle Park, North Carolina; Kormanik is Associate Silviculturist at the Forestry Sciences Laboratory, Athens, Georgia.

Two of the most striking visual differences among these plantations presently are the understory and the forest floor. Beneath white pine the understory is sparse, consisting mainly of ericaceous plants such as teaberry (*Gaultheria procumbens* L.) and pipsissewa (*Chimaphila maculata* (L.) Pursh). Under the other three pine species the understory is more typical of this area—oaks (*Quercus* spp.), red maple (*Acer rubrum* L.), dogwood (*Cornus florida* L.), poison ivy (*Rhus toxicodendron* L.), various species of the genus Vaccinium, plus an assortment of minor vegetation, most noticeable of which is honeysuckle (*Lonicera japonica* Thunb.) and the genus Viburnum. The forest floor under the loblolly pine appears appreciably thicker than under the other pines, and an almost continuous H layer has developed. Discontinuous H layers are evident beneath the shortleaf, white, and Virginia pines but they are thin and it is difficult to measure their thickness.

METHODS

Of the 10 original blocks established, five were not used because of the excessive variability of surface soil depth and texture. The blocks used in this study were quite homogeneous with respect to soil—all were classified as Tatum very fine sandy loam. The individual plots for each species in each block measured 1 by 2 chains and contained 242 trees at a spacing of 6 by 6 feet. Sampling was confined to the area inside the center 30 trees, approximately 720 square feet. Ten random sampling points were selected in each plot. At each

Generated on 2023-11-17 17:22 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Table 1.—Average survival, height, diameter, and basal area of trees in a 16-year-old species comparison test, Buckingham County, Virginia

Species	Survival	Height	Diameter	Basal area per acre
	Percent	*Feet*	*Inches*	*Sq. ft.*
Loblolly pine	76 (76) [1]	43 (44)	5.7 (5.8)	167 (175)
White pine	68 (65)	40 (40)	5.7 (5.9)	145 (142)
Virginia pine	74 (78)	37 (37)	4.8 (4.8)	118 (130)
Shortleaf pine	80 (80)	35 (37)	4.6 (4.9)	124 (129)

[1]Values in parentheses are averages for the five plots used in our study.

of these 10 points on each plot, both the forest floor and surface 3 inches of mineral soil were sampled in July and August of 1962.

Forest Floor: A 1-sq.-ft. frame was placed on the forest floor and a knife moved along the inside edge. The layers were separated as the floor was picked up and placed in paper bags. All samples had L and F layers, and some also had a thin H layer. The following criteria were used to divide the floor into layers. The L layer was all relatively undecomposed material dropped since the previous September. The F layer was partially decomposed material, still recognizable as to origin. This means there was a gradation from off-colored, whole needles near the L layer to bits of broken, partially decomposed needles (1/16 inch or less in size) near the bottom of the layer. The H layer was well decomposed organic matter, unrecognizable as to origin.

Mineral Soil: Mineral soil was collected at three depths: 0-1 inch, 1-2 inches, and 2-3 inches. Samples were collected with a push tube from soil bared when the forest floor was collected. Ten cores were taken at each square-foot sampling area and the material, separated by depths, was composited. Bulk density samples were collected at four random points in each plot using methods developed by Lutz.[2]

Laboratory Methods

The samples of forest floor material were ovendried at 60° C., weighed, and ground. Mineral soil samples were air dried and passed through a 2-mm. sieve; subsamples were then powdered for analyses of organic matter and nitrogen.

Calcium, Mg, K, and P were determined in forest floor samples with the following procedures. A 2-g. ovendry sample was ashed at 400° C. for 4 hours. The ash was taken up in 10 ml. of 8 *N* HCl, diluted to 100 ml., and filtered to make the "base" solution. Potassium, Ca, and Mg were analyzed on a flame spectrophotometer. Potassium was determined in the "base" solution, and Ca and Mg were determined in a 25-ml. aliquot by the method of Wells and Corey.[3] Phosphorus was determined in a 10-ml. aliquot by the molybdovanadate method.[4] Total N in the forest floor material and mineral soil was determined by the Kjeldahl method.

Ash content of forest floor was determined by burning an ovendry sample at 600° C. for 4 hours. All values for concentration of elements in the forest floor are on an ash-free basis.

Exchangeable K, Ca, and Mg were extracted from the mineral soil with 1.0 *N* NH_4OAc (buffered at pH 7) and analyzed with a Beckman DU spectrophotometer. Readily soluble P was extracted by the Truog method (0.002 *N* H_2SO_4 buffered at pH 3); pH was determined in a paste with a glass electrode; and carbon was determined by the dry combustion method on a carbon induction apparatus.[4]

A known volume of mineral soil was ovendried to a constant weight at 105° C. for bulk density determinations. Bulk density values were used to convert concentrations to pounds per acre.

[2]Lutz, J. F. Apparatus for collecting undisturbed soil samples. Soil Sci. 64: 399-401. 1947.

[3]Wells, C. G., and Corey, R. B. Elimination of interference by phosphorus and other elements in the flame photometric determination of calcium and magnesium in plant tissue. Soil Sci. Soc. Amer. Proc. 24 (3): 189-191. 1960.

[4]Jackson, M. L. Soil chemical analysis. 498 pp. Englewood Cliffs, N. J.: Prentice-Hall, Inc. 1958.

Generated on 2023-11-17 17:23 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Statistical Methods

Analysis of variance, with the following sources and degrees of freedom, was used to test for a species effect for each of 96 responses:

Source	d. f.
Blocks	4
Species	3
Experimental error	12
Sampling error	180

Bulk density of the mineral soil was analyzed the same way, except that sampling error had 60 degrees of freedom. No statistical analyses were run for the percentage values of elements in the H layer.

In addition, Tukey's w-procedure as given in Steel and Torrie[5] was used to test for significant differences between all possible pairs of species means.

RESULTS

Weight measurements confirmed visual observations—the forest floor beneath the loblolly stands was appreciably heavier than that beneath the other species (table 2). The L layer was heaviest beneath the loblolly, and it was the only species with an H layer thick enough to be measured or collected. Even here, the H layer was discontinuous—it was collected in 10 samples on one plot, was missing on one plot, and on the others it occurred in nine, eight, and three samples of the 10 collected. Climatic conditions of the Piedmont are such that a deep H layer is seldom found in upland forests.

The loblolly forest floor was also thicker than under the other species. When the weight of the total floor was divided by the depth, however, we found that unit weights for loblolly, shortleaf, and white pine floors were comparable, and that Virginia pine floor was considerably heavier. This resulted from the closer packing of the short Virginia pine needles.

The lower parts of the forest floor had higher average pH values than the upper parts. For white pine, the F layer pH was 0.8 unit higher than the L layer. For the other species, the difference was 0.1 or 0.2 pH unit. The only exception was the H layer under loblolly pine—the pH was the same as the L layer and 0.1 unit below the F layer.

[5]Steel, R. G. D., and Torrie, J. H. Principles and procedures of statistics. 481 pp. New York: McGraw-Hill. 1960.

The P, Ca, and N percentages were higher in the F layer than in the L layer for all species, and K and Mg were found in greater percentages in the L layer than in the F layer. The weight of P, K, Ca, Mg, and N was much greater in the F layer than in the L layer. This was expected because the volatile matter weight of the F layer is 3 to 6 times greater than the L layer. In the H layer of loblolly stands, the percentages of all elements except Mg were higher than those in L and F layers. The Mg percentage was slightly greater in the L layer than in the other layers. Since the weights of the L and H layers were not greatly different, the weights of nutrients in these layers differed slightly. The only exception was with N, where both the percentage and weight were considerably greater in the H layer.

The bulk density of mineral soil on all plots increased with depth but there were no significant differences between species. As a result, the percentage and weight values for all elements were ranked in the same order among the species.

The primary differences in the influence of species upon mineral soil were for soil reaction, available P, and exchangeable Ca (tables 2 and 4).

Soil reaction was highest beneath white pine, reflecting higher Ca content in the forest floor and 0-2 inch depth of mineral soil. The most acid condition was produced in the 0-1 inch depth under Virginia pine. Species influence upon soil reaction failed to extend into the 2-3 inch depth.

The greatest amount of available P in mineral soil occurred beneath white pine. Even though the percentage P was greatest, the white pine floor had the smallest amount present due to its relatively light weight.

The greatest amount of Ca was found under white pine for the surface 2 inches, and beneath Virginia pine for the 2-3 inch layer. In contrast to the situation with P there was more Ca in the forest floor under white pine than under the other species.

Mineral soil beneath Virginia pine contained the greatest amount of organic matter (OM). For the surface 3 inches of mineral soil, the only significant differences among the factors measured were in the weight of P and Ca between shortleaf and white pines, and in weight of P between white and Virginia pines. There were no

Generated on 2023-11-17 17:24 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Table 2.—Means for properties investigated under four pine species. (Values for concentrations of elements in forest floor are on an ash-free basis)

Layer	Property	Unit	Species			
			Loblolly	Shortleaf	Virginia	White
L	Volatile matter	lb./acre	3,951	2,260	2,113	2,480
	Ash	%	2.76	3.29	2.45	3.86
	pH		4.2	4.2	4.0	4.2
	P	%	.056	.062	.062	.074
	K	%	.081	.137	.137	.097
	Ca	%	.381	.469	.478	.978
	Mg	%	.089	.093	.069	.124
	N	%	.633	.717	.764	.823
	P	lb./acre	2.26	1.43	1.29	1.88
	K	lb./acre	3.30	3.06	2.75	2.47
	Ca	lb./acre	14.93	10.54	10.04	25.11
	Mg	lb./acre	3.48	2.18	1.46	3.07
	N	lb./acre	25.11	16.13	16.16	20.40
F	Volatile matter	lb./acre	14,513	11,265	12,657	7,034
	Ash	%	10.42	13.95	14.51	21.87
	pH		4.3	4.4	4.1	5.0
	P	%	.081	.092	.096	.133
	K	%	.066	.089	.074	.086
	Ca	%	.424	.608	.552	1.022
	Mg	%	.067	.087	.063	.101
	N	%	1.094	1.275	1.540	1.654
	P	lb./acre	11.86	10.09	11.92	9.36
	K	lb./acre	9.33	9.48	9.21	6.09
	Ca	lb./acre	57.96	65.00	68.65	73.24
	Mg	lb./acre	8.45	9.27	7.88	7.13
	N	lb./acre	159.34	142.01	194.08	111.37
H	Volatile matter	lb./acre	3,570			
	Ash	%	31.45			
	pH		4.2			
	P	%	.107			
	K	%	.097			
	Ca	%	.510			
	Mg	%	.085			
	N	%	1.499			
	P	lb./acre	3.61			
	K	lb./acre	3.33			
	Ca	lb./acre	17.47			
	Mg	lb./acre	2.90			
	N	lb./acre	52.80			
L+F+H	Thickness	inches	2.6	1.5	1.1	1.1
	Volatile matter	lb./acre	22,034	13,525	14,770	9,514
	P	lb./acre	17.73	11.52	13.21	11.24
	K	lb./acre	15.96	12.54	11.96	8.56
	Ca	lb./acre	90.36	75.54	78.69	98.35
	Mg	lb./acre	14.83	11.45	9.34	10.20
	N	lb./acre	237.25	158.14	210.24	131.77
0-1	pH		4.5	4.5	4.3	4.9
inch	P	p.p.m.	3.8	2.9	2.9	4.7
	K	p.p.m.	71	72	89	63
	Ca	p.p.m.	218	167	190	382
	Mg	p.p.m.	29	28	29	42
	N	%	.070	.073	.083	.079
	OM	%	2.94	2.72	3.06	2.87
	P	lb./acre	1.05	0.84	0.82	1.34
	K	lb./acre	19.86	20.84	25.69	18.17
	Ca	lb./acre	60.73	48.38	54.92	108.37
	Mg	lb./acre	7.69	8.13	8.45	11.98
	N	lb./acre	195.6	211.8	238.0	226.7
	OM	lb./acre	8,316	7,888	8,794	8,233
	C/N		25.3	22.0	21.3	20.0

Generated on 2023-11-17 17:24 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Table 2.—Means for properties investigated under four pine species. (Value for concentrations of elements in forest floor are on an ash-free basis) (continued)

Layer	Property	Unit	Species			
			Loblolly	Shortleaf	Virginia	White
1-2	pH		4.8	4.6	4.6	4.9
inches	P	p.p.m.	2.8	1.9	1.8	3.0
	K	p.p.m.	56	60	92	56
	Ca	p.p.m.	148	114	175	302
	Mg	p.p.m.	24	18	26	29
	N	%	.048	.052	.064	.052
	OM	%	1.92	1.99	2.26	1.89
	P	lb./acre	.87	.59	.56	.91
	K	lb./acre	17.83	18.86	28.47	16.76
	Ca	lb./acre	48.24	35.86	54.08	92.07
	Mg	lb./acre	7.53	5.76	8.11	8.72
	N	lb./acre	155.4	163.9	198.1	158.5
	OM	lb./acre	6,121	6,172	6,882	5,751
	C/N		23.7	22.5	22.0	22.1
2-3 inches	pH		4.9	4.8	4.8	5.0
	P	p.p.m.	2.0	1.4	1.7	2.6
	K	p.p.m.	48	57	95	43
	Ca	p.p.m.	127	103	174	161
	Mg	p.p.m.	20	18	26	24
	N	%	.043	.047	.052	.048
	OM	%	1.67	1.87	1.96	1.74
	P	lb./acre	.63	.46	.55	.78
	K	lb./acre	15.37	18.46	30.16	13.32
	Ca	lb./acre	39.75	33.37	55.74	49.17
	Mg	lb./acre	6.40	6.33	8.33	7.21
	N	lb./acre	136.7	152.4	162.7	148.1
	OM	lb./acre	5,267	5,559	6,156	5,582
	C/N		22.7	23.5	22.8	23.0
0-3	P	lb./acre	2.55	1.89	1.93	3.03
inches	K	lb./acre	53.06	58.16	84.32	48.25
	Ca	lb./acre	148.72	117.61	164.74	249.61
	Mg	lb./acre	21.62	20.22	24.89	27.91
	N	lb./acre	487.7	528.1	598.8	533.3
	OM	lb./acre	19,704	19,619	21,832	19,566
Floor						
+ 0-3	P	lb./acre	20.28	13.41	15.14	14.27
inches	K	lb./acre	69.02	70.70	96.28	56.81
	Ca	lb./acre	239.08	193.15	243.43	347.96
	Mg	lb./acre	36.45	31.67	34.23	38.11
	N	lb./acre	724.95	686.24	809.04	665.07
	OM	lb./acre	41,738	33,144	36,602	29,080
0-1 inch	Bulk density		1.25	1.28	1.26	1.27
1-2 inches	Bulk density		1.42	1.38	1.35	1.34
2-3 inches	Bulk density		1.40	1.44	1.39	1.34

significant differences in the carbon-nitrogen ratio (C/N) with respect to either species or depth of soil.

By combining the weights of elements in the forest floor and the surface 3 inches of mineral soil, we found that loblolly pine had the most P and organic matter, Virginia pine had the most K and N, and white pine had the most Ca and Mg.

The significant differences between species are shown in tables 3, 4, and 5.

DISCUSSION

Forest floors vary in thickness and composition, and separation of the material into specific layers is often difficult. In this study, separation of the lower F layer from the H layer was no simple matter because, rather than a sharp demarcation line, there was a gradual transition between the two. Thus, when comparing organic matter or nutrients of forest floors, the weight of the total floor was a much better criterion than was weight of individual layers.

Generated on 2023-11-17 17:24 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Table 3.—Significant differences, between four pine species, for weight and chemical properties of forest floor studied

Species	Layer	PROPERTIES[1]		
		Shortleaf pine	White pine	Virginia pine
Loblolly pine	L	$Volatile_{wt}$ **P_{wt}** **N_{wt}**[2]	$Volatile_{wt}$ **$Ash_{\%}$** **$P_{\%}$** $Ca_{\%}$ **$Mg_{\%}$** $N_{\%}$	$Volatile_{wt}$ **P_{wt}** **Mg_{wt}** **N_{wt}**
	F		**$Volatile_{wt}$** $Ash_{\%}$ pH $P_{\%}$ $Ca_{\%}$ **$Mg_{\%}$** $N_{\%}$	$N_{\%}$
	H	$Volatile_{wt}$ P_{wt} K_{wt} Ca_{wt} Mg_{wt} N_{wt}	$Volatile_{wt}$ P_{wt} K_{wt} Ca_{wt} Mg_{wt} N_{wt}	$Volatile_{wt}$ P_{wt} K_{wt} Ca_{wt} Mg_{wt} N_{wt}
Shortleaf pine	L		$Ca_{\%}$ **Ca_{wt}**	
	F		**$Ash_{\%}$** pH $P_{\%}$ **$Ca_{\%}$** $N_{\%}$	$N_{\%}$
	H			
White pine	L			$Ash_{\%}$ **pH** $Ca_{\%}$ $Mg_{\%}$ **Ca_{wt}** **Mg_{wt}**
	F			**$Ash_{\%}$** pH $P_{\%}$ $Ca_{\%}$ **$Mg_{\%}$** **N_{wt}**
	H			

[1]Properties shown in cells are significantly different between the two species which intersect to form the individual cells.

[2]Properties set in boldface are significant at 5% level; all others are significant at 1% level.

When collecting samples of the forest floor, we found great variation—even among samples several feet apart. We attributed this variation to (1) tendency of material to collect in the old field furrows; (2) the sloughing of bark, which creates a thicker floor near the base of trees; (3) our inadvertent inclusion of mineral soil as we scraped up the lowest layer of the floor; (4) the depositing of minerals in the floor by fauna (for example, great quantities of mineral soil that were carried upwards by ants and other insects).

To reduce the weight variation between samples of the forest floor, the percentage volatile matter (100 minus ash percentage) was determined for all organic samples. This percentage was applied to the oven-dry weights, thus all forest floor weights were on a volatile-matter basis. The lower layers of the forest floor had a greater percentage of ash than did the surface layers. For the L layer, with little mineral soil contamination, the ash represented primarily the nonvolatile elements in the organic tissue. For the F and H layers most of the ash weight was mineral matter, even though decomposition of the organic matter increased the concentration of nonvolatile elements in these layers.

There were considerable differences between some of the forest floors studied; differences in the mineral soil were not so great. Since no data are available on soils prior to treatment, it is not possible to ascribe to species all differences now found in the mineral soil. It appears that if soil changes develop along indicated trends, mineral soil under white pine will be higher in Ca, Mg, and available P, and less acid than soils under the other pine species. These changes are indicated by a higher Ca and Mg content of the foliage of white pine. Nitrogen, although slightly higher

Generated on 2023-11-17 17:24 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Table 4.—Significant differences, between four pine species, for chemical properties of the surface 3 inches of mineral soil

Species	Layer	PROPERTIES[1]		
		Shortleaf pine	White pine	Virginia pine
	Inches			
Loblolly pine	0-1		**pH**[2]	
	1-2			
	2-3			
Shortleaf pine	0-1		**pH Ca_{ppm} Ca_{wt}**	
	1-2		**pH Ca_{ppm} Ca_{wt}**	
	2-3		**P_{ppm} P_{wt}**	
White pine	0-1			pH **Ca_{ppm} Ca_{wt}**
	1-2			**pH P_{wt}**
	2-3			

[1]Properties shown in cells are significantly different between the two species which intersect to form the individual cells.

[2]Properties set in boldface are significant at 5% level; all others are significant at 1% level.

under Virginia pine, is expected to remain low or become lower in concentration in the mineral soil and continue to accumulate in the forest floor for all species. The greatest N accumulation is expected in the forest floor of loblolly pine.

These stands are young and have had a relatively short time to produce a stable forest floor and influence the mineral soil. Sampling these plantations when they are older will be necessary if we are to draw more definite conclusions about the influence of these trees on the mineral soil.

Generated on 2023-11-17 17:25 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA

Table 5.—Significant differences, between four pine species, for properties of the combined forest floor and surface 3 inches of mineral soil

Species	Layer	PROPERTIES[1]		
		Shortleaf pine	White pine	Virginia pine
Loblolly pine	L+F+H	Volatile$_{wt}$ **P_{wt}** **Mg_{wt}**[2] N_{wt} Thickness	Volatile$_{wt}$ **P_{wt}** Mg_{wt} N_{wt} K_{wt} Thickness	**Volatile$_{wt}$** **K_{wt}** Mg_{wt} Thickness
	0-3 inches			
	L+F+H + 0-3 inches	**P_{wt}** **OM_{wt}**	**P_{wt}** OM_{wt}	
Shortleaf pine	L+F+H			
	0-3 inches		**P_{wt}** **Ca_{wt}**	
	L+F+H + 0-3 inches		**Ca_{wt}**	
White pine	L+F+H			N_{wt}
	0-3 inches			**P_{wt}**
	L+F+H + 0-3 inches			**OM_{wt}**

[1]Properties shown in cells are significantly different between the two species which intersect to form the individual cells.

[2]Properties set in boldface are significant at 5% level; all others are significant at 1% level.

Generated on 2023-11-17 17:25 GMT / https://hdl.handle.net/2027/umn.31951d03001959t
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from UNIVERSITY OF MINNESOTA